SKETCH

OF THE

PHYSIOLOGY AND PATHOLOGY OF THE TEETH,

AS FOUNDED ON THEIR MINUTE STRUCTURE.

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In the minute anatomy of the teeth, the most remarkable circumstance is the structure of their canal, cavity, and tubules. In their physiology, the most remarkable circumstance is the gradual closure of these cavities. In their pathology, every thing probably depends on such circumstances. Yet no one seems to have thought of these considerations in their diseases.

In relation to this subject, and even fundamental to it, Heusinger, in his *System der Histologie*, part i., 1822, says "all organisms, and all the elementary parts of organic bodies, have at first the globular form"—"all organisms, in their development, pass from the globular to the vesicular structure"—"when, in the organism, globules and the structureless mass exist, they are led by natural laws to arrange themselves in linear order, so as to form fibres." This remarkable generalization has been illustrated by many recent discoveries.

The first great discovery which might have had its foundation in this, with regard to the minute organization of living bodies, was Sleiden's, as to the development and structure of plants being universally cellular. Schwann, in his *Mikroskopische Untersuchungen*, 1839, proved that this was equally true as to animals, and that all the primary tissues of the animal frame are cellular.

Preparatory to illustrating these principles in the structure of the teeth, it may be observed that the dentine presents a vascular canal, a pulp cavity, and many calcigerous tubes radiating from it.

Now Purkinjé (whose investigations of the structure of the teeth are published by Fraenkel, in his Thesis *De Penitiori Dentium Humanorum Structura Observationes*, 1835, and by Raschkow, in his *Meletemata circa Dentium Evolutionem*, 1835,) describes the parenchyma of the pulp, which produces the dentine, as "*composed of minute uniform spherical granules;*" and these granules, according to Schwann, are "*round nucleated cells*, between which run vessels and nerves;" while the *elongated globules*, described by these anatomists as being more regularly arranged at the surface of the pulp, with their long axes directed outwards, are *cylindrical cells*, which contain nuclei with their nucleoli.

After Leeuwenhoeck and Malpighi, it was Purkinjé who first observed that the dentine of the growing teeth consisted of *fibres*, directed from the pulp to the outer surface; and Schwann, on examining these *fibres*, found that, while *corresponding in size*

to the cylindrical cells, they were much larger than the dentinal tubules of Retzius, to be subsequently mentioned. Hence he expressly states, that "*the cylindrical cells of the pulp are the fibres of the tooth in their first stage*, and that *these cells of the pulp, becoming filled with animal matter, and ossified, form the fibres of Purkinjé.*[1]

Thus the doctrine that the cells of the dentine have, for their animal basis, the cells of the pulp itself, existing in that body before being hardened, and continuing, as we see, in organic connexion with it, after their conversion into dentine, is both, in each of its parts, and as a whole, due solely and exclusively to the German anatomists.

Leeuwenhoeek, however, had, long before, discovered that the dentinal fibres were really tubes, and he sent to the Royal Society of London an account of his discovery, which was published under the title of *Microscopical Observations on the Structure of Teeth and other Bones*, with a figure of the tubes, in the 140th Number of the *Philosophical Transactions*, 1678, p. 1002. The dentine was there described as "formed of tubules, spreading from the cavity in the centre to the circumference," and presenting one hundred and twenty tubules within the forty-fifth part of an inch.

Unnecessary as it may be for the learned reader, I must (in order that my subsequent inductions may be understood by all) complete this very slight and brief historical sketch of the minute anatomy of the teeth.

The discovery of Leeuwenhoeck, that the dentine is made up by minute tubes, proceeding from the inner to the outer surface of the tooth, was recently confirmed by Purkinjé, who added an account of their direction. He also thinks these fibres tubular, because, on being brought into contact with ink, it was drawn in by capillary attraction; a fact which is confirmed by Müller.

Müller observed that these tubes are filled with granules of calcareous substance; that the white colour of a tooth is confined to these tubes, which are imbedded in a semi-transparent substance; and that their whiteness and opacity were removed by acids.

On breaking a thin lamella of a tooth transversely to the direction of its fibres, and examining the edge, he observed projecting tubes, which were white and opaque, straight, and apparently not flexible; but, if the tooth had been previously acted on by acid, the tubes were transparent and flexible. Hence he inferred that the tubes have distinct walls, consisting of animal tissue, and that, besides their cavity containing earthy matter, their tissue is impregnated with it.

[1] See also accounts of this and relative doctrines in various Numbers of the *British and Foreign Medical Review*.

Retzius, in his *Mikroskopiska Undersökningar*, 1837, next examined the cartilage in teeth, which had been macerated in muriatic acid, and, on making sections of it, found that it appeared to consist of slightly undulating fibres, lying close together, rising by one extremity from the pulp, whilst the other extremity terminated near the surface of the tooth.

When very thin slices of the dentine also were examined with the microscope, Retzius found it to be composed of hollow fibres and ramifying tubes, the trunks of which opened into the cavity of the tooth, whilst their terminations, in extremely fine branches, ran towards the surface.

When the wall of the cavity of the pulp, moreover, is viewed under a glass of sufficient magnifying power, it is found to be perforated like a sieve, and to present an immense number of orifices, which are the mouths of the main tubes.

Retzius discovered the exact size, course, and arrangement of the tubules, the dichotomous branching of the primary tubes, the minuter ramules sent, throughout the course of the main tubes, into the interspaces, the calcigerous cells with which those ramules communicate, the terminal ramifications of the tubules, and the anastomoses of the ramules with each other, with the intertubular cells, and with those at the periphery of the dentine.

As to their directions, he showed that the tubes do not run in straight lines except towards the apices of the teeth, but form generally two or three curves, their particular degree of flexion varying in different teeth, and in different parts of the same tooth.

The tubular form so employed, it should be observed, displays a relation to power of resistance in the direction of the greatest pressure.

Purkinjé showed that the dentine contained also an intermediate or intertubular tissue. This, however, he described as structureless, and as entering into the dentine in greater proportion than the tubes. Retzius, however, detected the cells of the intertubular substance; and, according to the researches of Schwann, the basis of the intertubular tissue throughout possesses a fibrous structure; he says that "the *fibres* of Purkinjé *coalesce* so as to *constitute* the intertubular substance of the teeth, leaving spaces in which the dentinal tubules are at a subsequent (?) period developed."

Numerous conjectures have been formed as to the use of all these cavities, by Retzius, Müller, Schwann, and some of the most distinguished anatomists; but no satisfactory account of it has yet been given.

My brother, Mr Alexander Nasmyth of London, in his *Researches on the Teeth*, remarks, that "the theory of a tubular system will be found to present some internal contradictions.

"'It can scarcely be doubted,' says Retzius, 'that the minute

tubes in dentine, in the cortical substance, in common bone, and in the horns of deer, as well as the cells with which they are in connexion, are *a peculiar kind of vessels containing a nourishing and supporting fluid.*' In another part of his work, however, he says, ' with respect to the contents of the canals, I, as well as Professor Müller, have found that they consist of an inorganic or earthy substance, which appears white when viewed on a dark ground, but which disappears when the preparation is placed in diluted muriatic acid. When the light falls into these canals, this matter is seen to be composed apparently of *infinitely fine particles, adhering together in lumps.*'

" How a tube," says Mr A. Nasmyth, " can be ' filled with osseous matter,' and at the same time allow of the circulation of a ' nourishing and supporting fluid,' I cannot understand. It must not be forgotten, too, that Retzius allows ' that, in the tooth, no renovation of the material appears to take place.' "

" What end, then," says Retzius, " is served by this beautiful organization of the dentine? We have many examples that nature organises structures which have a close affinity to each other, according to one and the same plan; and hence we have, in different parts or organisms, formations, which in some are of great importance, whilst in others they are of much less functional significance, or of none whatever. (!) If we hence assume, what is highly probable, that, in bone, *the peculiar vessels* in question give passage to fluids during the entire life of the animal (or a great part of it),—which fluids contain the solid as well as the liquid materials of the osseous substance,—it does not necessarily follow, that, in the teeth, the same process must be carried on during the whole of life. On the contrary, I am inclined to believe that *these vessels* in dentine are at their height during the first period of the formation of the tooth, and exercise then their more perfect action. At the same time, the existence of a continual vital process in the tooth, as well as in the crystalline lens, cannot be denied [it should be shown *why*], which, however, appears to be carried on without any constant exchange of solid matter, and must hence consist in a *renovating circulation of the dental fluids.* [Without exchange of matter, there can be no renovating circulation.] I refer here to an observation of G. H. Weber, published several years ago, and before the existence of the peculiar vessels in question was suspected: —' The tooth appears to be penetrated by fluids secreted by the dental germ, and by the membrane surrounding the root externally, (both of which are abundantly supplied with vessels). These fluids, without circulating in organic canals, may operate much towards the preservation of the tooth, [it should be shown *how*], as also towards the decay of the dentine when its composition is morbid.' "

Retzius, in short, allows that he is ignorant of the specific functions of the tubes in the dentine of the adult tooth.

"In common bone, probably," says he, "*the peculiar vessels* in question take a part in the continual, or apparently continual, exchange of substance; this cannot, in the same degre, be the case in dentine, inasmuch as, in this, no such exchange appears to take place."

The function of this elaborate contexture of branched and anastomosing tubes and cells, says Mr Owen, "is supposed by Retzius to be conveying, by capillary attraction, a slow current of nutritive or preservative fluid, through the entire substance of the tooth; which fluid might be derived either from the superficies of the pulp in the internal cavity of the tooth, or from the corpuscles or cells of the external layer of cortical substance or cœmentum, with the tubes radiating from which corpuscles the fine terminal tubes of the dentine anastomose."

"What then," says Schwann, in ignorance of this point, "are the dentinal tubes? Retzius compares them with the calcigerous tubes that radiate from the bone-corpuscles; and I was of the same opinion. But I have given up these ideas since I observed nothing of the kind in human teeth."

"The calcareous salts," says Retzius, "were probably left behind in the tubes *from the first formation* of the dentine, and deposited themselves around the parietes of the tubes and cells." That is to say, there was probably a superabundance of lime; and as, in an ill built chimney, it would, in such case, be squeezed out between the bricks or stones, so, in the tubules of the teeth, it is found in their interior. But nature, assuredly, does nothing in this wasteful and useless way.

Well, therefore, might Mr A. Nasmyth say, "Further research, more varied experiments, and a more rigid examination of the subject in all its departments and bearings, are absolutely required, before the *doctrine* of a tubular system can be considered as immutably established." The fact, however, that the tubular system exists, seems to be immutable enough: its nature and use is the present question.

We have now seen that the dentine consists of an animal basis, forming minute tubes and cells, and of calcareous particles, either entering into their composition, and that of their interspaces, or contained in their cavities in a granular state; and that, besides earth, the tubes and cells contain a colourless liquid, which is, doubtless, plasma separated from the blood.

Thus, some of the ablest and most distinguished anatomists and physiologists see this. They have before their eyes both the plasma, or the material, and the calcareous granules which are formed from it, — they know, too, that nature gradually closes both the tubules and the cavity,—they actually detect her in the

secret operation of effecting this,—and yet they exclaim, "What end, then, is served by this beautiful organization of the dentine?" And they make conjectures as to materials "*left behind* from the first formation of the dentine." But let us critically follow them.

As to the function of the parts now described, Retzius says, that the delicate branches of the tubules form, as it were, *a peculiar vascular system.* "It can scarcely be doubted, that the minute tubes in dentine, in the cortical substance, in common bone, and in the horns of deer, as well as the cells which are united with them, are *a peculiar kind of vessels*, containing a nourishing and supporting fluid."

I am confident, on the contrary, that these tubules, &c. were originally *the common blood-vessels of the teeth;* and I shall here adduce the testimony of physiologists, unbiassed by hypothesis, to prove this.

Purkinjé describes the pulp as consisting of a congeries of nearly uniform globules, without vessels or nerves; but as afterwards displaying both of these. "*Blood-vessels*," says he, "soon penetrate the granular pulp, form several anastomoses in their course through its substance, and terminate in a delicate capillary net-work on that part of the surface of the pulp where the dentine has begun to be formed." And Serres states, that "all around the insertion of the internal membrane into the bulb, *the vessels* are much more numerous than at any other part," and that "they form there a vascular circle, or vascular circles, which descend in proportion as ossification advances, — these vascular areolæ corresponding in number with the roots of the teeth."

Hence F. Cuvier conceives the dental pulp to be composed entirely of *blood-vessels* and nerves; and hence also, as observed by Hunter, if a young animal is fed with madder for some time, and then killed, those parts of the teeth which were formed during the period the animal was taking the madder, are found coloured.

But we have proofs yet more direct. The dentine in the teeth of a few mammals actually presents *canals containing blood-vessels*, or a vascular pulp, and is therefore termed vascular.

"In the dog-fish," says Mr Owen, "the medullary canals of the teeth are occupied by a *sanguineous medulla*, closely resembling that which fills the medullary cells of the coarse bone of which the base of the tooth is composed, and with which cells the anastomosing reticulate canals of the crown of the tooth are directly continuous."

"In certain animals," says Retzius, "the cortical substance presents also larger canals, which are of about the same thickness as the medullary canals in bone. In the cortical substance, closing, in some teeth, the end of the cavity of the pulp, which

would else be open, those tubes open into the said cavity, and contain *the blood-vessels* which belong to the pulp itself. The larger tubes which are found in that portion of the cortical substance lying exposed beyond the gum, appear empty, and are probably only the remains of *the blood-vessels* which were engaged in its formation. It is, however, still probable, that even in this substance a *circulation* is kept up of peculiar fluids secreted from the blood, which fluids rise into the peculiar minute tubes and cells, in much the same manner as the sap rises in a plant." This last, a little reflection will show, is not clear.

"The horns of deer," says the same physiologist, "are organized in nearly the same manner, with this difference only, that in them *the minute medullary threads* appear to be *really blood-vessels*, which view is most strongly confirmed by Berthold in his work *Ueber das Wachstum*, &c. * * * In the horns of deer, in which *the blood-vessels occupy, in a great measure, the place of the medullary fibres and of the medullary tubes, the same minute osseous vessels are seen radiating from the parietes of the canals which contain these blood-vessels.*"

The same physiologist (whose words I quote because he declares his inability to explain these phenomena, yet liberally furnishes the means of doing so to others) says, "In common bone, probably, *the peculiar vessels* in question take a part in the continual, or apparently continual, exchange of substance. This cannot, in the same degree, be the case in dentine, inasmuch as in this no such exchange appears to take place." It will now be seen *why* it does not.

It is a remarkable fact, that *the parenchyma of the pulp decreases* in proportion as the dentine increases, and is withdrawn, as it were, into *the dental cavity, which, at the same time, becomes gradually contracted.*

Retzius, moreover, ascertained that the tubes of the dentine are of considerably less diameter than the globules of the blood; and Purkinjé and Müller agree with him in stating, that *the tubes of the dentine, besides being several diameters smaller than the globules of the blood, are also filled with a calcareous inorganic substance.*

Müller, in particular, instituted researches which prove that parts of the tubules are filled with inorganic calcareous salts.

He says, "when the light falls on fine polished lamellæ of dentine, the white colour of the tooth is soon seen to be owing to these tubes or fibres, and the intermediate substance is more transparent;" and, moreover, "when such sections are submitted to the action of an acid, the white colour of the fibres disappears, the remaining cartilages still presenting tubes in their interior, which however, when dried, are no longer white.

In fine polished sections of carious teeth, also, Müller could easily see with the microscope, that where they were transparent, *a crumbly substance was contained in parts of the tubules;* and that this substance was more coherent in the tubules of the white tracts: by adding diluted acids, he also observed under the microscope that this crumbly substance was dissolved.

Retzius found, with Professor Müller, that the contents of the canals consisted of an inorganic or *earthy substance*, which, when seen on a dark ground, seems *white*, and which disappears when the preparation is submitted to the action of diluted muriatic acid. When the light falls into the canals, this matter is seen to be composed apparently of *infinitely fine particles, adhering together in lumps.* "I am convinced," he says, "that the tubules are excavations in the substance of cartilage as well as in that of bone, which partly contain *a clear liquid* and partly *deposits of calcareous salts.*

The same law extends to inferior animals. "In all the genera of sharks," says Mr Owen, "the body of the tooth is principally occupied with the two kinds of canals, medullary and calcigerous, as he terms them. The latter are, however, essentially minute branches or continuations of the former, and although, in the newly formed tooth, distinguishable by the nature of their contents, yet this difference is gradually obliterated by the progressive deposition of calcareous matter by concentric layers in the medullary canals."

Thus it appears, that *the canal of the root, the cavity of the body, and the tubules, become gradually narrower, and are at length obliterated;* the earthy matters deposited from the plasma predominate over the gelatinous; vessels and nerves no longer penetrate the tooth; its vitality becomes extinguished; and it drops out, presenting a phenomenon similar to the shedding of the horn in the cervine tribes.

THUS IT IS NOT, AS RETZIUS AND THE OTHER WRITERS QUOTED SUPPOSE, TO PRESERVE, BUT GRADUALLY TO EXTINGUISH THE VITALITY OF THE TEETH THAT THE TUBULES ARE SUBSERVIENT. It is a remarkable fact that to a similar end tend the changes which nature effects on some other organs, as the heart and arteries, and that equally by means of calcareous deposits in their animal parenchyma,—an act, however, which, in that case, is perhaps altogether morbid.

Some, indeed, would be disposed to consider the character of the changes produced, as preservative. Be it so: but it is preservative only by destroying vitality, as I have just shown. The character of the dentinal cavities, however, cannot reasonably be drawn from the few months of their early, but from the many years of their adult existence,—not from their brief existence as blood-vessels in the fœtus or the infant, about which there can

be no dispute, but from their existence as plasma and calx-conveying tubules in the adult, which constitutes the whole question under discussion.

Some again think they pay less homage to nature by assuming that she intelligently labours to terminate vitality when its continuance would be useless or injurious, than by assuming that she struggles for a vital end, and always blunderingly oversteps it by destroying the life of the part! I need not contend with these.

Round the roots and neck of the teeth, Retzius found the other structure, the cement or cortical substance, which enters into the composition of the teeth, and which presents some similarity to the osseous tissue.

It sometimes extends from the neck where the enamel terminates, and is continued to the extremity of the root, increasing in thickness as it descends. In one instance, Purkinjé says, he observed that this substance was continued in a layer of extreme tenuity upon the enamel of a human incisor; such cases are, I believe, very rare.

Viewed under the microscope, the cement presents the same cellules or so-called corpuscula as the proper osseous substance, dentine, and most cartilaginous structures. "When either recent or dried cortical substance," says Retzius, "polished, or in fine slices, is examined with a good lens, a number of white, crowded points, almost invisible to the naked eye, are discovered in it, which, on being farther magnified, show themselves to be the cells above mentioned, deriving their white colour from the osseous matter they contain. As in dentine and common bone numerous tubes pass into and from them, widening as they enter, and giving them the appearance of irregular stars. These tubes have numerous communications with each other, partly direct, and partly by means of branches 1-1000th to 1-5000th of a line in diameter; some of them pass immediately from one cell to another, precisely as in the dentine. The osseous cells are of various forms and sizes; some elongated, so as to look almost like tubes; some nearly round. Their average size, Retzius found to be 1-150 line. In sections made transversely to the axis of the tooth, it appears that the osseous cells are arranged in parallel lines or concentric rings, some fainter than others, or that the cortical substance is deposited in delicate coherent layers.

The cement always corresponds in texture with the bones of the animal it belongs to, and, when of sufficient thickness, is like them traversed by vascular canals. It is the most vascular of the dental tissues, and forms a bond of union between the unvascular constituents of the tooth and the vascular bone in which it is implanted. The hardening material of the cement is distributed like that of the dentine, and renders its cells opaque.

In relation to dental pathology, one or two points may be alluded to, merely as illustrating the applicability of the preceding principles.

The softening of the decayed portion of a tooth seems to depend upon the removal of the earthy salts from the containing tubes and cells; and it is well known that, after tubuli, &c., are hardened and filled, odontalgia rarely occurs.

These two facts afford the important pathological indication of stopping carious teeth, which, though adopted and acted upon only empirically, is in reality thus founded upon strictly philosophical principles.

In relation to this point, it should be determined whether there is any external sign (colour, or any other) of these cavities being filled; and also, whether any circumstances seem to hasten or to retard the filling of the cavities.

Mr Fox says, that "if the teeth, after their first formation, received no supply from vessels, or did not require any nourishment, it would have been better if they had been destitute of any internal cavity, and of regular organization. As tubules, &c., however, remain patent during many years, they no doubt continue so, to serve a useful purpose.

It is a remarkable fact, that the older a tooth is, and the more the cavity of the pulp is closed, the thicker in general is the cortical substance at the end of the root, where it sometimes forms a considerable enlargement, or what is commonly called an exostosis. "The deposition of cement," says Retzius, "round the root of the tooth, increases as the cavity of the pulp closes, and as the pulp itself correspondingly diminishes. The minute osseous tubes in the cortical substance then form immediate communications with the osseous cells and osseous tubes in the dentine, so that the latter can now, when the pulp has nearly ceased to exist, receive the necessary supply of liquids only from without.

I suspect that such views, in relation to the minute structure of the teeth, will afford another basis for the dentistic art, which has never, I believe, been founded on minute structure, although disease must depend on that, and that alone.